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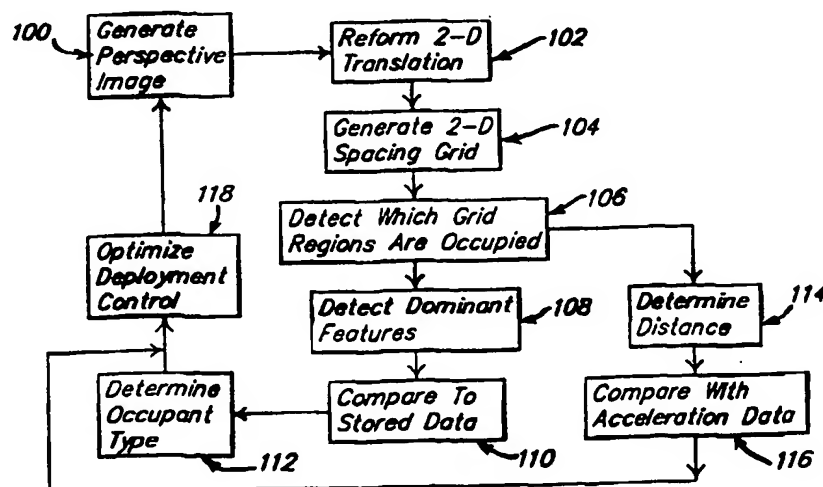
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(54) Title: OCCUPANT TYPE AND POSITION DETECTION SYSTEM



## (57) Abstract

A method and system (10) for detecting vehicle occupant type and position utilizes a single camera unit (12) positioned, for example at the driver or passenger side A-pillar, to generate image data of the front seating area of the vehicle. The present invention distinguishes between objects, forwardly or rearwardly facing child seats, and occupants, by periodically mapping the image taken of the interior of the vehicle into an image profile (104), and utilizing image profile matching with stored profile data (110) to determine the occupant or object type. The system and method of the present invention track occupant type and position in both parallel and perpendicular directions relative to a fixed structure such as the vehicle instrument panel to optimize both the efficiency and safety in controlling deployment of a occupant safety device, such as an air bag (28).

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## OCCUPANT TYPE AND POSITION DETECTION SYSTEM

BACKGROUND OF THE INVENTION

The present invention relates generally to motor vehicle crash discrimination systems utilized for actuating or  
5 deploying a passenger safety restraint, and more specifically to a system and method for detecting occupant seating conditions so as to optimize deployment of a passenger safety restraint.

Conventional vehicle crash discrimination systems  
10 typically employ at least one mechanical, electromechanical, or electronic acceleration sensor affixed to the vehicle for sensing vehicle acceleration. The output of the sensors are supplied to a discrimination circuit for comparison to a predetermined threshold value. If the predetermined threshold  
15 value is exceeded, the discrimination circuit will output a signal which actuates or deploys a passenger safety restraint, such as an air bag or passive seat belt mechanism.

However, conventional mechanical or electromechanical accelerometer based crash discrimination systems do not account  
20 for variations in passenger/occupant conditions in determining whether to actuate the safety restraint. More specifically, conventional accelerometer based crash discrimination systems are generally designed to assume nominal conditions, such as 50th percentile male, actual presence of a vehicle occupant,  
25 and failure of an occupant to wear a seat belt. The assumption of these crash conditions are necessary to insure proper actuation of the safety restraint when severe deceleration of the vehicle is detected by the accelerometer. Such assumptions inherently cause unnecessary, undesired, or improperly-timed  
30 actuation of the safety restraint in conditions where no occupant is present, in marginal crash situations where a seat belt provides sufficient safety protection for the occupant, or in situations where the occupant is improperly positioned relative to the safety restraint such that actuation of the  
35 safety restraint could potentially injure the occupant.

Thus, since conventional crash discrimination systems can not accommodate various occupant conditions which affect the desirability of actuating the safety restraint, they have not proven to be completely satisfactory. In response, the prior art has attempted to overcome these deficiencies by providing arrangements which are generally directed at detecting occupant presence, size, or position relative to some fixed structure in the vehicle. The following are examples of such prior art arrangements.

US 5,413,378 to Steffens, Jr., et al disclose a system for controlling an occupant restraint, such as an air bag, wherein the system utilizes a combination of a set of ultrasonic occupant position sensors, and various seat and occupant weight sensors, to determine occupant weight and position relative to fixed structure with the vehicle.

US 5,398,185 to Omura discloses a system for optimizing deployment of passenger restraint devices which utilizes a combination of a plurality of seat sensors, a card reader for inputting data regarding the physical characteristics of the occupant, and two telecameras to compute a value characteristic of each interior vehicle element and the occupant's estimated behavior relative thereto.

US 5,366,241 to Kithil discloses an overhead-mounted air bag deployment system which utilizes an overhead passenger sensor array to sense position and velocity of an occupant's head so as to control deployment of an air bag, and to detect and provide warning when the occupant is in an unsafe seated condition.

US 5,074,583 to Fujita et al disclose a vehicle collision detection system which utilizes a plurality of seat-mounted sensors to detect occupant seating condition, position, and size in order to optimize inflation of an air bag in a vehicle collision.

In addition, commonly owned U.S. Patents 5,446,661 and 5,490,069 each disclose a method and system for vehicle crash discrimination which continuously detects various vehicle occupant positions for optimizing a discrimination analysis to

achieve increased efficiency and reliability in actuating a safety restraint.

While these arrangements may have provided an improvement in efficiency over conventional crash discrimination systems, there still exists a need for a crash discrimination system which can further optimize or tailor air bag deployment based on the specific type of occupant present in the vehicle. More specifically, with the increased use and availability of air bags in motor vehicles has come the realization that deployment of an air bag in certain crash situations, and with certain types of occupants, such as infants strapped into a child safety seat, has the potential of causing more harm to the occupant than if the air bag were not deployed.

As noted above, this problem has become particularly acute with infant safety seats. The prior art has attempted to distinguish passengers from infant child seats by using conventional distance measuring techniques to detect the amount and extent of possible occupant movement, or alternatively has used weight sensing arrangements to detect the weight of any object which might be located on the vehicle seat. In either arrangement, threshold values are used to classify an object as either a passenger or an inanimate object.

However, simply using weight sensors or movement monitoring has not provided the level of discrimination between occupant types or the reliability necessary to achieving effective "smart" control over air bag deployment. As a result, a need still exist for a system which can automatically and continually determine occupant type and position in a reliable and cost effect manner.

#### SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide a system and method which automatically determines the type of occupant in a vehicle seat, as well as the location of that occupant within the seat relative to fixed structure in the interior of the vehicle, such as the dashboard or steering

wheel, so as to increase efficiency and reliability in actuating or deploying a safety restraint such as an air bag.

It is another object of the present invention to provide a system and method which is capable of detecting the presence of either a person, a rearward facing infant car seat, a forward facing infant car seat, or a box or other inanimate object, so as to increase efficiency and reliability in actuating or deploying a safety restraint such as an air bag..

It is a further object of the present invention to provide a system and method which determines if an occupant is in an unsafe seated position to optimize control over deployment of an occupant safety restraint such as an air bag or other passive restraint device.

In accordance with these and other objects, the present invention provides a system and method which detects occupant position and type which utilizes a single camera unit positioned for example at the driver or passenger side A-pillar. The present invention provides a system and method which distinguishes between objects, forwardly or rearwardly facing infant seats, and adult occupants by periodically mapping an image taken of the interior of the vehicle into image profile data, and utilizing image profile matching with stored reference profile data to determine the occupant or object type. Instantaneous distance is also measured and changes in the measured distances are tracked. All of this information is then used to optimize deployment control of at least one passenger safety restraint.

Thus, in accordance with a first aspect of the present invention, a system for determining vehicle occupant type and position relative to a fixed structure within the vehicle comprises an imaging means mounted at a single location within the vehicle interior and having a predetermined field of view so that a front driver side seat and a front passenger side seat are both simultaneously viewable by said imaging means, but not simultaneously in focus as described more fully hereinbelow. The imaging means generates an output signal representative of an instantaneous position for any object



located within the field of view. The system further includes means for storing predetermined object profile data characteristic of a plurality of different types of objects when situated in either front seat of the vehicle, and a processor means for identifying the type of object located in the front seats of the vehicle by comparing the imaging means output signal to the predetermined object profile data.

In accordance with a second aspect of the present invention, a method for determining position of an object located in a vehicle relative to a fixed structure within the vehicle comprises the steps of generating two-dimensional image data representative of any objects located within a front seating area of the vehicle, generating a two-dimensional range grid by vertically dividing the front seating area into a plurality of independent regions each representative of a predetermined size of the vehicle interior, wherein the fixed vehicle structure such as the instrument panel is located proximate to one end region, and the vehicle front seats are located proximate with the opposite end region, detecting lateral location of the object relative to a narrow depth of focus reference plane using a de-blurring filter, and determining distance from the fixed structure by comparing the generated image data with the range grid to detect which if any of the plurality of regions are occupied by an object.

In achieving both of these aspects, the system and method of the present invention further comprise discriminating between objects and occupants; A-pillar positioning of the imaging system; use of a perspective angle correction lens; use of a two-dimensional range grid; tracking the change in instantaneous occupant position to predict a crash situation; optimization of passenger restraint deployment based on the identification of occupant type and position; generating the two-dimensional range grid by either etching the grid on a lens element, printing the grid on a CCD element, or utilizing suitable programming in a processor means; and estimating occupant lateral distance from a fixed vehicle interior component by utilizing a narrow depth of focus lens in

combination with suitable electromechanical or image processing auto-focus techniques.

The present invention will be more fully understood upon reading the following detailed description of the preferred embodiment in conjunction with the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a schematic illustration of a vehicle occupant type and position detection system in accordance with the present invention;

Fig. 2 is a side view of the vehicle interior showing location of the system of the present invention;

Fig. 3 is a downward view of the vehicle interior illustrating the field of view for the system of the present invention;

Figs. 4 (a) and (b) are a side view of a "person" type occupant and the corresponding two dimensional ranging grid image of the present invention;

Figs. 5 (a) and (b) are a side view of an infant safety seat and the corresponding two dimensional ranging grid image of the present invention; and

Fig. 6 is a flowchart illustrating the operation of the present invention.

#### DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

Referring to Fig. 1, there is shown a system 10 which determines vehicle occupant position and type in accordance with the present invention. In accordance with the preferred embodiment, system 10 is suitably adapted for mounting in a single location, such as the driver or passenger side A-pillar location as shown in Fig. 2, so as to have a field of view allowing the system to "see" any region within the driver side seat and the passenger side seat area for a given focal depth. The use of a single location advantageously reduces the amount of necessary hardware, and therefore the cost and complexity of manufacturing and installation of the present invention.

More specifically, in accordance with the preferred embodiment, a single camera unit 12 is located at the A-pillar

or similar location so as to have a perspective field of view simultaneously covering both driver and passenger side seats. The camera unit 12 is preferably a low light infra red (IR) sensitive type camera system, and is arranged to provide all light operation through the inclusion of a supplemental light source, such as represented by an LED 14. However, one of ordinary skill in the art will readily appreciate that other types of camera systems may be suitable, and as such the use of an IR camera system 12 is not to be construed as limiting the present invention.

A perspective angle correcting lens 16 is employed to translate the perspective image of the interior of the vehicle into a two-dimensional image signal which is then output to an image processor 18. In other words, lens 16 is optically designed to effectively remove the "perspectiveness" of the image created by the slant angle of the camera 12 with respect to a plane passing perpendicular to the instrument panel through the center of the passenger seat, as more clearly shown in Fig. 3. The correction lens 16 removes distortion in the image pixels inherently caused by the perspective view and makes the pixels all equal in actual distance spacing as if being two-dimensionally viewed from the side of the vehicle.

In further accordance with the present invention, system 10 utilizes a de-blurring filter arrangement 19 in conjunction with a narrow depth of focus reference plane. With a narrow depth of focus, points along a perpendicular plane are in focus, and objects either farther or closer than this plane are out of focus. Thus, the location of an object relative to the focus plane can be inferred from the amount of blur in the image, i.e., the farther an object is laterally displaced from the focus plane, the more the image will be blurred.

The de-blurring filter, while symbolically shown in Fig. 1, is preferably implemented as an algorithm subroutine in image processor 18. Therefore, with a narrow depth of focus and de-blurring filter arrangement, image processor 18 is able to infer or estimate the location of an object relative to the focus plane, while also being able to ignore or distinguish

background clutter within the viewable image, such as door features or the driver depending on which side of the car the system is located, from the desired image of the occupant or object within the seat.

5           The system 10 further includes a grid pattern 20 that is either etched on the lens 16, screen printed on a CCD, or implemented by suitable programming within the image processor 18. This grid pattern is customized for each model of automobile, and as best illustrated in Figs 4(a)-(b) and 5(a)-  
10       (b) provides an actual distance spacing metric for the pixels in the image along the plane perpendicular to the instrument panel. As described hereinbelow, the grid pattern 20 is the mechanism by which the image processor 18 will be able to measure the actual distance of objects within the image focal  
15       plane, and to otherwise detect dominate features of an object or occupant located in the vehicle seat. The grid is effectively normalized by using lateral location derived from the narrow depth of focus reference plane and the de-blurring filter arrangement.

20           In addition, the light source is preferably etched with a matching pattern of grid marks. The relative warping of the transmitted light by the occupant provides for detection of fine shape features which may not be otherwise discernable in poor lighting conditions due to reduced image contrast. Such  
25       a warped grid analysis also provides a three-dimensional profile of the occupant which can be used in conjunction with the detected lateral distance to provide comprehensive information regarding occupant size, shape, and location within a vehicle seat.

30           The overall operation of the present invention as well as the remaining elements of Fig. 1 will now be discussed in context with the flow chart shown in Fig. 6. At step 100, the camera unit 12 generates a perspective image signal which is translated at step 102 by lens 16 into a two-dimensional  
35       image data signal representative of the profile of any objects located within a front seat of the vehicle. At step 104, a two-dimensional spacing or range grid is created by vertically

dividing the two-dimensional image of the front vehicle seating area into a plurality of independent regions each representative of a predetermined size of the vehicle interior. The grid is oriented so as to substantially locate the fixed vehicle structure at one end region, and the vehicle front seats substantially at the opposite end region, as particularly shown in Figs 4(b) and 5(b).

At step 106, the two-dimensionally generated image data is analyzed against the spacing grid to detect which if any of the plurality of regions are occupied by an object or occupant. The image processor 18 utilizes an image analysis algorithm which detects the dominant features and position of the object located in the vehicle seat at step 108. These features include the relative extent of the vertical portion of the occupant relative to the horizontal portion as shown in Figs. 4(b) or 5(b).

Object profile data representative of a set of reference features of various types of occupants, such as humans, forward and rearward facing infant safety seats, or other inanimate objects, are stored in a suitable memory device 21, such as a RAM or EEPROM. The stored sets of reference features are scaled to allow identification of a complete range of occupant sizes, i.e., small children to large adults. In addition, since there are a variety of different sized infant seats, a size invariant classification of reference features is provided for proper identification of infant seats. Image processor 18 then determines occupant type at step 112 by mapping or comparing the detected dominant features of the two dimensional image signal with the set of reference features stored in memory 21 at step 110.

In addition to determining occupant type, the distance between the occupant and the instrument panel or steering wheel of the vehicle is detected at step 114 by measuring the relative location of the occupant based on the regions of the two-dimensional grid which are detected as being occupied at step 106. The actual distance is derived by combining the measured location within the grid with the

lateral location of the object relative to narrow focus plane provided by the camera lens as determined by the de-blurring filter operation.

5 The motion of the occupant is determined by looking for areas of relative motion and instantaneous distance changes through the grid zones, and to estimate the relative speed of the motion in these areas. Such information and the respective instantaneous changes in distance are stored, such as in memory 21. At step 116, the data generated from this process is compared with contemporaneous vehicle speed data input on a line 22 from a centralized microprocessor air bag deployment control unit 24, or directly from one or more vehicle acceleration sensors (not shown). This comparison step facilitates an analysis by either processor 18 or 24 of the motions of the occupants during either precrash or noncrash braking situations, which subsequently allows processor 24 to predict the onset of a crash and/or to develop an optimal deployment strategy for the air bags, or other restraints such as pretensioners and energy management systems.

20 After determining occupant type and position at steps 112 and 116 respectively, at step 118 the image processor 18 provides an output signal 26 to the control unit 24, which subsequently optimizes control over the actuation, or deployment, of one or more passenger safety restraints, such as an air bag 28, or the activation of an audible or visual warning device(s) 30 via at least one output line 32. The warning devices 30 provide an alert for the vehicle occupant of a potentially hazardous seating condition.

30 Therefore, with the present invention, the vehicle occupant type and position detection system 10 is designed to provide both high frequency detection of the type of occupant or object located in a vehicle, and measurements of the position of the driver and/or passengers relative to potential impact points such as the steering wheel and dashboard, and to process that information so as to provide an optimized safety restraint deployment decision. The system 10 thus allows the deployment control processor unit 24 to refrain from deploying

an air bag when a infant safety seat is present, particularly a rearward facing infant seat, or when a person is present but is too close, thereby preventing the explosive force with which an air bag is inflated from doing substantial harm to the infant or person.

It will be further understood that the foregoing description of the preferred embodiment of the present invention is for illustrative purposes only, and that the various structural and operational features herein disclosed are susceptible to a number of modifications, none of which departs from the spirit and scope of the present invention as defined in the appended claims.

## WE CLAIM:

1. A system for determining vehicle occupant type and position relative to a fixed structure within the vehicle comprising:

5           an imaging means mounted at a single location within the vehicle interior and having a predetermined field of view so that a front driver side seat and a front passenger side seat are both simultaneously viewable by said imaging means but not simultaneously in focus, wherein said  
10           imaging means generates an output signal representative of an instantaneous position of any object located within the field of view;

15           a memory for storing predetermined object profile data characteristic of a plurality of different types of objects when situated in either front seat of the vehicle; and

20           a processor means for identifying the type of object located in the front seats of the vehicle by comparing said imaging means output signal to said predetermined object profile data.

2. The system of claim 1 wherein said processor means comprises means for determining the distance between an object located within the field of view and the fixed structure within the vehicle based on said imaging means output signal.

3. The system of claim 2 further comprising means for optimizing deployment of a passenger safety restraint based on the identified type of object and distance.

4. The system of claim 3 further comprising means for storing instantaneous distance measurements, and means for tracking changes in the instantaneous distance measurements, wherein said means for optimizing safety restraint deployment



5 comprises means for predicting a vehicle crash based on said tracked changes in distance.

5. The system of claim 2 further comprising:

means for generating two-dimensional image data representative of any objects located within the predetermined field of view; and

5 means for generating a two-dimensional range grid which vertically divides the field of view into a plurality of independent regions each representative of a predetermined size of vehicle interior space, wherein said grid is oriented so that the fixed vehicle structure is located proximate with one end region, and the vehicle front seats are located proximate with the opposite end region, wherein said means for determining distance comprises means for  
10 comparing said generated two-dimensional image data with said range grid to detect which if any of the plurality of regions are occupied by an object.  
15

6. The system of claim 5 wherein said imaging means comprises a lens element, and said means for generating a two-dimensional range grid comprises a grid pattern etched on the surface of said lens element.

7. The system of claim 6 wherein said imaging means further comprises means for transmitting light into the predetermined field of view, and said means for generating a two-dimensional range grid further comprises a grid pattern  
5 etched onto said light transmitting means which matches said grid pattern etched onto said lens element.

8. The system of claim 5 wherein said imaging means comprises a CCD element, and said means for generating a two-

dimensional range grid comprises a grid printed on said CCD element.

5 9. The system of claim 8 wherein said imaging means further comprises means for transmitting light into the predetermined field of view, and said means for generating a two-dimensional range grid further comprises a grid pattern etched onto said light transmitting means which matches said grid pattern etched onto said CCD element.

5 10. The system of claim 5 further comprising a narrow depth of focus lens coupled to said imaging means and a de-blurring filter coupled to said processor means, wherein said means for determining the distance is responsive to said narrow depth of focus lens, said de-blurring filter, and said two-dimensional grid for estimating the absolute distance based on the lateral location of the object within the field of view relative to the fixed structure of the vehicle.

5 11. The system of claim 1 wherein said single location comprises a vehicle A-pillar, and wherein said imaging means further comprises a perspective angle correction lens for translating the predetermined field of view from a perspective view to a two-dimensional view.

12. The system of claim 1 further comprising means for optimizing deployment of a passenger safety restraint based on the identified type of object.

13. The system of claim 5 wherein said means for generating two-dimensional image data comprises a processor having a deblurring algorithm.

14. A method for determining position of an object located in a vehicle relative to a fixed structure within the vehicle comprising the steps of:

generating two-dimensional image data representative  
of any objects located within a front seating  
are of the vehicle;

generating a two-dimensional range grid by  
vertically dividing the front seating area into  
a plurality of independent regions each  
representative of predetermined size of vehicle  
interior, wherein the fixed vehicle structure  
is located proximate with one end region, and  
the vehicle front seats are located proximate  
with the opposite end region; and

detecting lateral location of the object relative to  
a narrow depth of focus reference plane using a  
de-blurring filter; and

estimating the distance between the object and said  
fixed structure by comparing said generated  
image data with said range grid and detected  
lateral location to determine which if any of  
the plurality of regions are occupied by an  
object.

15. The method of claim 14 wherein said step of  
generating a two-dimensional range grid comprises etching said  
grid onto the surface of a lens element used to generate said  
two-dimensional image data.

16. The method of claim 14 wherein said step of  
generating a two-dimensional range grid comprises the step of  
printing said grid on a CCD element used to generate said two-  
dimensional image data.

17. The method of claim 14 wherein said step of  
generating a two-dimensional range grid comprises etching  
matching grid patterns onto each of a light transmitting and  
receiving component used to generate said two-dimensional image  
data, and further comprising the step of estimating a profile  
of any object located within the front seating area by

detecting warping of the transmitted light grid relative to the receiving light grid.

18. The method of claim 14 further comprising the steps of:

storing predetermined object profile data characteristic of a plurality of different types of objects when situated in either front seat of the vehicle; and

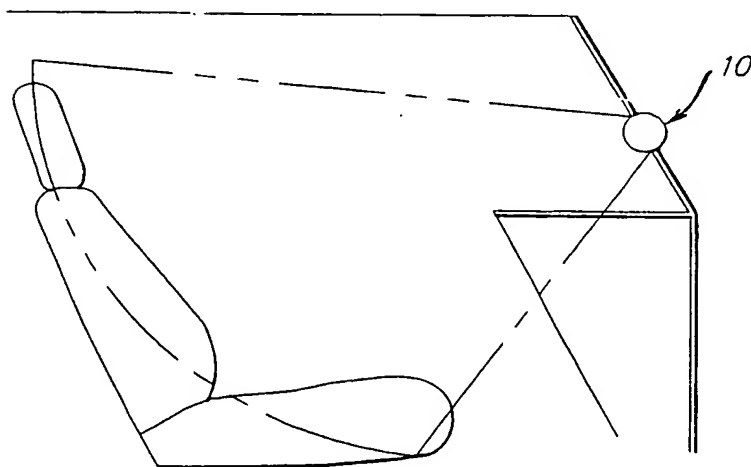
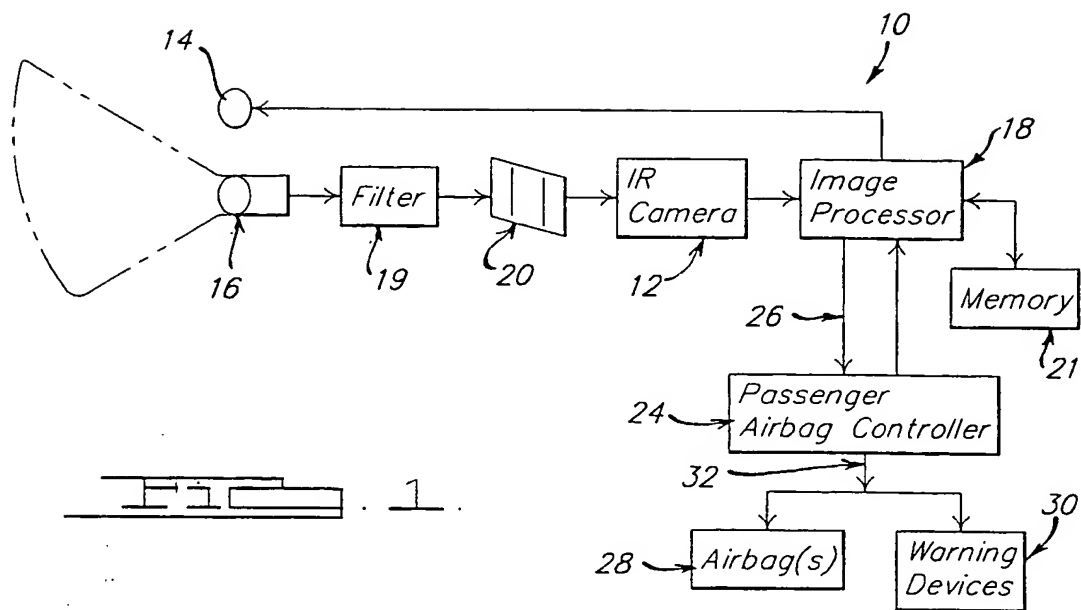
identifying the type of object located in the front seats of the vehicle by comparing said two-dimensional image data to said predetermined object profile data.

19. The method of claim 18 further comprising the step of optimizing deployment of a passenger safety restraint based on the identified type of object and distance.

20. The method of claim 19 further comprising the steps of storing instantaneous distance measurements, and tracking changes in the instantaneous distance measurements, wherein said optimizing step comprises the step of predicting a vehicle crash based on said tracked changes in distance.

21. The method of claim 14 wherein said step of generating two-dimensional image data comprises the step of positioning an imaging system having a predetermined field of view at a single location within the vehicle.

22. The method of claim 21 wherein said single location comprises a vehicle A-pillar, and wherein said step of generating two-dimensional image data further comprises the step of translating the predetermined field of view from a perspective view to a two-dimensional view.



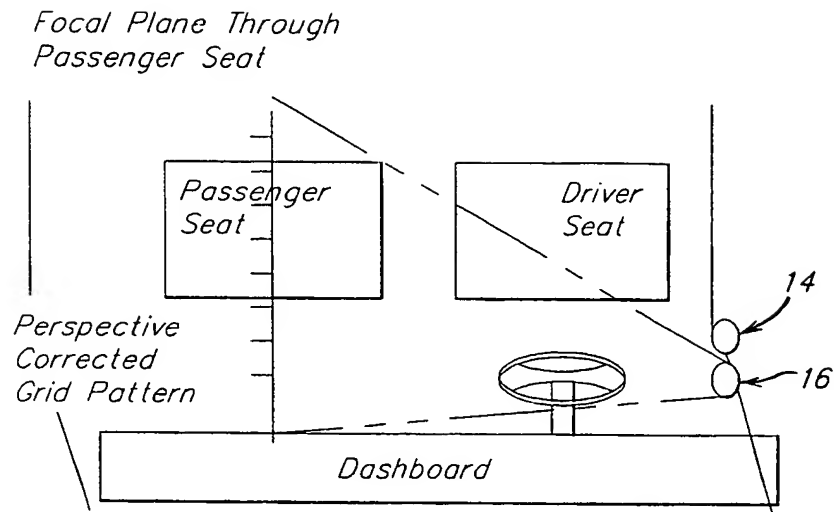


FIG. 3.

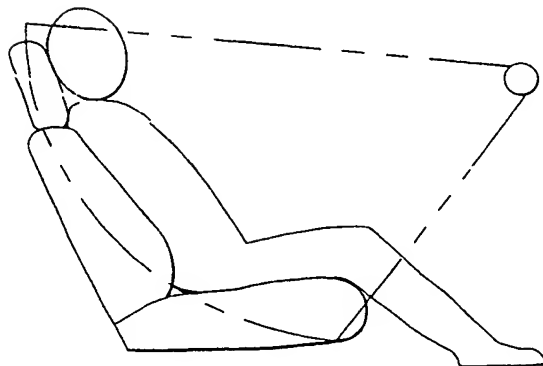


FIG. 4 (a).

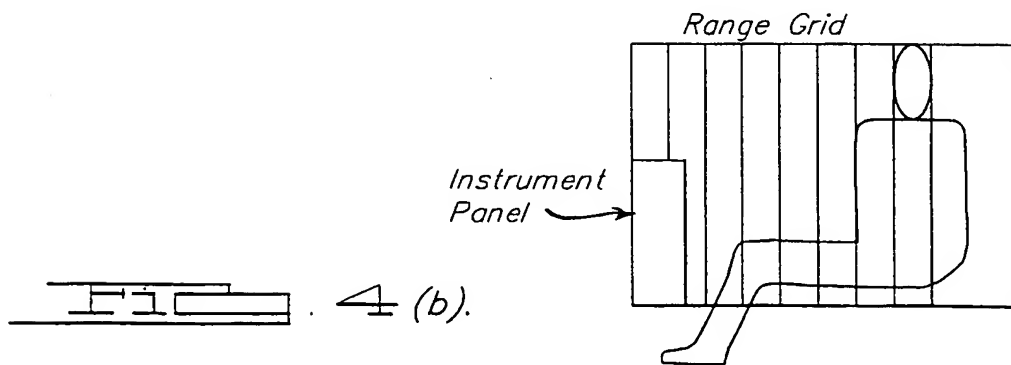


FIG. 4 (b).

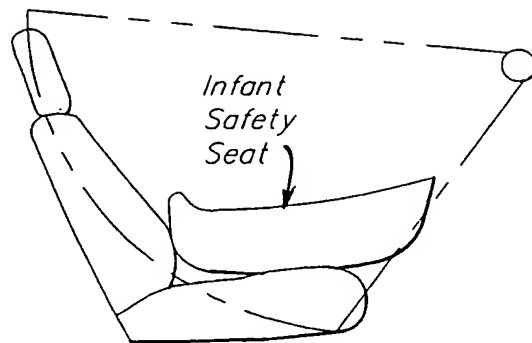
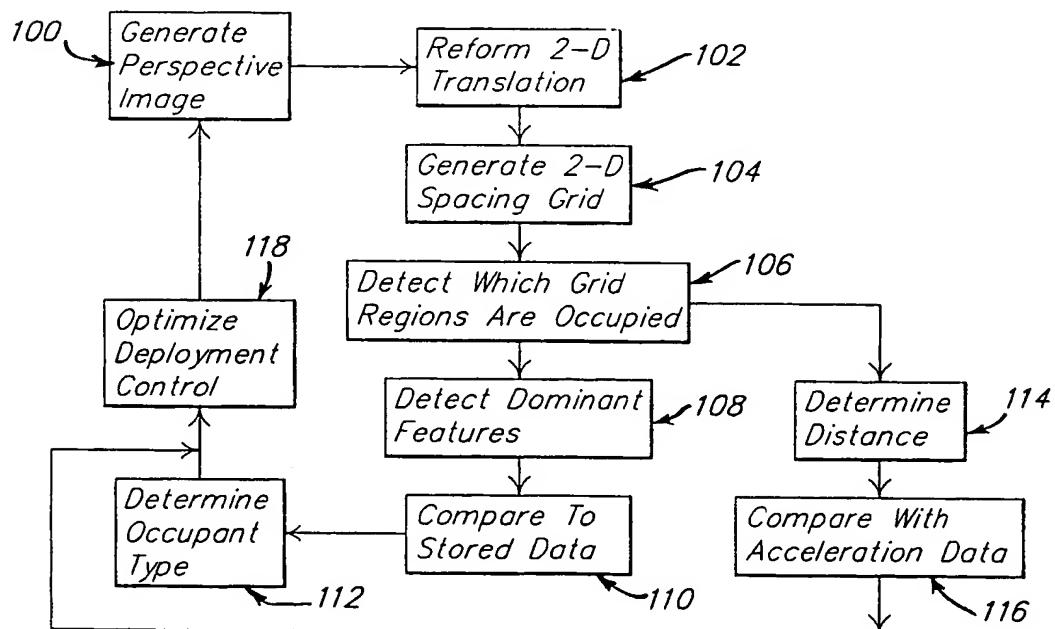
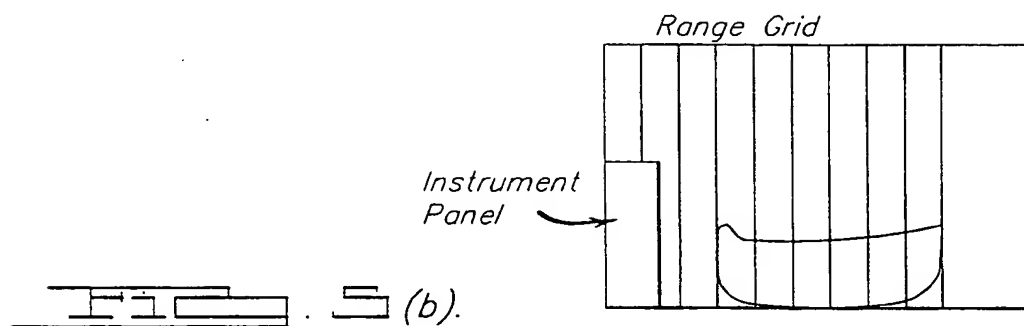


FIG. 5 (a).



## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US98/07685

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : G06K 9/00; B60R 21/32

US CL : 382/103, 106, 107; 701/45; 280/735

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 382/103, 106, 107; 701/45; 280/735

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS, IEEE

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,528,698 A (KAMEI et al) 18 June 1996, col. 3, lines 23-30, col. 4, lines 10-26, and col. 9, lines 44-51.	1-4, 11-12
Y	US 5,490,069 A (GIOUTSOS et al) 06 February 1996, col. 3, lines 42-49 and col. 4, lines 44-60.	2-4, 11-12

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☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

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Date of the actual completion of the international search

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